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(54) **CATHODE ACTIVE MATERIAL FOR LITHIUM ION BATTERY, CATHODE FOR LITHIUM ION BATTERY, AND LITHIUM ION BATTERY**

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(57) **ABSTRACT**

There is provided a cathode active material for a lithium ion battery having good battery properties. The cathode active material for a lithium ion battery is represented by a composition formula: $Li_xNi_{1-y}M_yO_{2+\alpha}$ wherein M is one or more selected from Sc, Ti, V, Cr, Mn, Fe, Co, Cu, Zn, Ga, Ge, Al, Bi, Sn, Mg, Ca, B, and Zr; $0.9 \le x \le 1.2$; $0 < y \le 0.7$; and $\alpha > 0.1$, and has a moisture content measured by Karl Fischer titration at 300° C. of 1100 ppm or lower.

13 Claims, No Drawings

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CATHODE ACTIVE MATERIAL FOR LITHIUM ION BATTERY, CATHODE FOR LITHIUM ION BATTERY, AND LITHIUM ION BATTERY

TECHNICAL FIELD

The present invention relates to a cathode active material for a lithium ion battery, a cathode for a lithium ion battery, and a lithium ion battery.

BACKGROUND ART

For cathode active materials for lithium ion batteries, lithium-containing transition metal oxides are usually used. The lithium-containing transition metal oxides are specifically lithium cobaltate ($LiCoO_2$), lithium nickelate ($LiNiO_2$), lithium manganate ($LiMn_2O_4$), and the like, and making these into a composite has been progress in order to improve properties (capacity enhancement, cycle properties, preservation properties, internal resistance reduction, and rate characteristic) and enhance safety. For lithium ion batteries in large-size applications as for vehicles and road leveling, properties different from those for cellular phones and personal computers hitherto are demanded.

For the improvement of battery properties, various methods have conventionally been used, and for example, Patent Literature 1 discloses a production method of a cathode material for a lithium secondary battery, in which method a lithium nickel composite oxide represented by a composition of

$$Li_xNi_{1-y}M_yO_{2-\delta}$$

wherein $0.8 \le x \le 1.3$ and $0<y \le 0.5$; M denotes at least one element selected from the group consisting of Co, Mn, Fe, Cr, V, Ti, Cu, Al, Ga, Bi, Sn, Zn, Mg, Ge, Nb, Ta, Be, B, Ca, Sc, and Zr; and δ corresponds to an amount of oxygen deficiency or an amount of oxygen excess, and $-0.1<\delta<0.1$ is passed through a classifying machine to be separated into the oxide having large particle diameters and the oxide having small particle diameters at an equilibrium separation particle diameter Dh of 1 to 10 μm, and the oxide having large particle diameters and the oxide having small particle diameters are blended at a weight ratio of 0:100 to 100:0. Then, the Patent Literature states that a cathode material for a lithium ion battery having various balances between rate characteristic and capacity can easily be produced.

CITATION LIST

Patent Literature

[Patent Literature 1] Japanese Patent No. 4175026

SUMMARY OF INVENTION

Technical Problem

Although the lithium nickel composite oxide stated in Patent Literature 1 contains an excessive amount of oxygen in the composition formula, there is still room for improvement as a high-quality cathode active material for a lithium ion battery.

Then, an object of the present invention is to provide a cathode active material for a lithium ion battery having good battery properties.

Solution to Problem

As a result of exhaustive studies, the present inventor has found that a close correlation exists between the amount of oxygen in a cathode active material and the battery properties. That is, it has been found that good battery properties can be obtained when the amount of oxygen in a cathode active material is a certain value or larger.

It has also been found that a close correlation exists between the moisture content and further the amount of moisture absorption of a cathode active material, and the battery properties. That is, it has been found that particularly good battery properties can be obtained when the moisture content in a cathode active material is a certain value or lower, or further when the amount of moisture absorption of a cathode active material is a certain value or lower.

An aspect of the present invention completed based on the above-mentioned findings is a cathode active material for a lithium ion battery represented by a composition formula:

$$Li_xNi_{1-y}M_yO_{2+\alpha}$$

wherein M is one or more selected from Sc, Ti, V, Cr, Mn, Fe, Co, Cu, Zn, Ga, Ge, Al, Bi, Sn, Mg, Ca, B, and Zr; $0.9 \le x \le 1.2$; $0<y \le 0.7$; and $\alpha>0.1$,

wherein a moisture content measured by Karl Fischer titration at 300° C. is 1100 ppm or lower.

In an embodiment of the cathode active material for a lithium ion battery according to the present invention, the moisture content measured by Karl Fischer titration at 300° C. is 800 ppm or lower.

In another embodiment of the cathode active material for a lithium ion battery according to the present invention, M is one or more selected from Mn and Co.

In further another embodiment of the cathode active material for a lithium ion battery according to the present invention, $\alpha>0.15$ in the composition formula.

In further another embodiment of the cathode active material for a lithium ion battery according to the present invention, $\alpha>0.20$ in the composition formula.

In further another embodiment of the cathode active material for a lithium ion battery according to the present invention, a moisture content measured by Karl Fischer titration at 150° C. is 300 ppm or lower.

In further another embodiment of the cathode active material for a lithium ion battery according to the present invention, the moisture content measured by Karl Fischer titration at 150° C. is 200 ppm or lower.

In further another embodiment of the cathode active material for a lithium ion battery according to the present invention, a difference between a moisture content measured by Karl Fischer titration at 300° C. and a moisture content measured by Karl Fischer titration at 150° C. is 100 to 500 ppm.

In further another embodiment of the cathode active material for a lithium ion battery according to the present invention, the difference between a moisture content measured by Karl Fischer titration at 300° C. and a moisture content measured by Karl Fischer titration at 150° C. is 100 to 130 ppm.

In further another embodiment of the cathode active material for a lithium ion battery according to the present invention, a moisture content measured by Karl Fischer titration at 150° C. is 1500 ppm or lower after the cathode active material is left in the air at a humidity of 50% and at 25° C. for 24 hours.

In further another embodiment of the cathode active material for a lithium ion battery according to the present invention, the moisture content measured by Karl Fischer titration at 150° C. is 1200 ppm or lower after the cathode active material is left in the air at a humidity of 50% and at 25° C. for 24 hours.

In further another embodiment of the cathode active material for a lithium ion battery according to the present invention, a moisture content measured by Karl Fischer titration at 150° C. is 300 ppm or lower after the cathode active material is left at a dew point of −80° C. for 24 hours.

In further another embodiment of the cathode active material for a lithium ion battery according to the present invention, the moisture content measured by Karl Fischer titration at 150° C. is 200 ppm or lower after the cathode active material is left at a dew point of −80° C. for 24 hours.

Another aspect of the present invention is a cathode for a lithium ion battery using the cathode active material for a lithium ion battery according to the present invention.

Further another aspect of the present invention is a lithium ion battery using the cathode for a lithium ion battery according to the present invention.

Advantageous Effect of Invention

The present invention can provide a cathode active material for a lithium ion battery having good battery properties.

DESCRIPTION OF EMBODIMENTS

(Constitution of a Cathode Active Material for a Lithium Ion Battery)

As a material for the cathode active material for a lithium ion battery according to the present invention, compounds useful as cathode active materials for usual cathodes for lithium ion batteries can broadly be used, but particularly lithium-containing transition metal oxides such as lithium cobaltate ($LiCoO_2$), lithium nickelate ($LiNiO_2$), and lithium manganate ($LiMn_2O_4$) are preferably used. A cathode active material for a lithium ion battery according to the present invention produced using such a material is represented by a composition formula:

$$Li_xNi_{1-y}M_yO_{2+\alpha}$$

wherein M is one or more selected from Sc, Ti, V, Cr, Mn, Fe, Co, Cu, Zn, Ga, Ge, Al, Bi, Sn, Mg, Ca, B, and Zr; $0.9 \le x \le 1.2$; $0 < y \le 0.7$; and $\alpha > 0.1$.

The ratio of lithium to the whole metal in the cathode active material for a lithium ion battery is 0.9 to 1.2; and this is because with the ratio of lower than 0.9, a stable crystal structure can hardly be held, and with the ratio exceeding 1.2, a high capacity of the battery cannot be secured.

The cathode active material for a lithium ion battery according to the present invention excessively contains oxygen as indicated as $O_{2+\alpha}$ ($\alpha > 0.1$) in the composition formula; and in the case of using the cathode active material for a lithium ion battery, battery properties such as capacity, rate characteristic, and capacity retention rate become good. Here, α is preferably $\alpha > 0.15$, and more preferably $\alpha > 0.20$.

The cathode active material for a lithium ion battery according to the present invention is a cathode active material for a lithium ion battery, the active material having a moisture content as measured by Karl Fischer titration (JIS K0113, general rules for methods of potentiometric, amperometric, coulometric, and Karl Fischer titrations) at 300° C. of 1100 ppm or lower. Karl Fischer's method is a method of measuring moisture by using a Karl Fischer's reagent (constituted of iodine, sulfur dioxide, a base, and a solvent such as an alcohol) to selectively and quantitatively react with water as in the following formula.

$$I_2 + SO_2 + 3\ \mathrm{Base} + ROH + H_2O \rightarrow 2\ \mathrm{Base} + HI + \mathrm{Base} + HSO_4R$$

A sample is added to an electrolyte solution containing as main components an iodide ion, sulfur dioxide, a base, and a solvent such as an alcohol, and electrolytically oxidized to thereby generate iodine as in the following formula and to thereby immediately cause Karl Fischer reaction.

$$2I^{2-} - 2e \rightarrow I_2$$

Since iodine is generated in proportion to an electricity quantity based on "Faraday's law," the amount of moisture can be determined immediately from the electricity quantity required for the electrolytic oxidation (1 mg of water=10.71 coulombs).

If a cathode active material for a lithium ion battery contains an amount of moisture exceeding a predetermined amount, battery properties of the lithium ion battery using the cathode active material become poor. As seen in the cathode active material for a lithium ion battery according to the present invention, if the moisture content measured by Karl Fischer titration at 300° C. is 1100 ppm or lower, battery properties, such as cycle properties, high-temperature operation, and storage properties, of a lithium ion battery using the cathode active material become good. The moisture content measured by Karl Fischer titration at 300° C. is preferably 800 ppm or lower, and more preferably 300 ppm or lower.

The cathode active material for a lithium ion battery according to the present invention, further, preferably has a moisture content measured by Karl Fischer titration at 150° C. of 300 ppm or lower. If the moisture content measured by Karl Fischer titration at 150° C. is 300 ppm or lower, battery properties, such as cycle properties, high-temperature operation, and storage properties, of a lithium ion battery using the cathode active material become better. The moisture content measured by Karl Fischer titration at 150° C. is preferably 200 ppm or lower, and more preferably 120 ppm or lower.

In the cathode active material for a lithium ion battery according to the present invention, a difference between a moisture content measured by Karl Fischer titration at 300° C. and a moisture content measured by Karl Fischer titration at 150° C. is preferably 100 to 500 ppm. If the difference in the moisture content therebetween is 100 to 500 ppm, the cycle properties of a lithium ion battery using the cathode active material become good. The difference between a moisture content measured by Karl Fischer titration at 300° C. and a moisture content measured by Karl Fischer titration at 150° C. is more preferably 100 to 170 ppm, and still more preferably 100 to 130 ppm.

The cathode active material for a lithium ion battery according to the present invention preferably has a moisture content measured by Karl Fischer titration at 150° C. of 1500 ppm or lower after the cathode active material is left in the air at a humidity of 50% and at 25° C. for 24 hours. By allowing the cathode active material to have such a property, the cathode active material hardly absorbs moisture even if being stored in a high-humidity space, and the moisture content can well be controlled. The moisture content measured by Karl Fischer titration at 150° C. after the cathode active material is left in the air at a humidity of 50% and at 25° C. for 24 hours is more preferably 1200 ppm or lower, and still more preferably 700 ppm or lower.

The cathode active material for a lithium ion battery according to the present invention preferably has a moisture content measured by Karl Fischer titration at 150° C. of 300 ppm or lower after the cathode active material is left at a dew point of −80° C. for 24 hours. The reason of measuring at a dew point of −80° C. is because the measurement is carried out so as not to be influenced by the amount of moisture in the measurement environment. By allowing the cathode active material to have such a property, the cathode active material hardly absorbs moisture even if being stored in a space whose temperature is lower by 80° C. than the dew point, and the moisture content can well be controlled. The moisture content measured by Karl Fischer titration at 150° C. after the cathode active material is left at the dew point of −80° C. for 24 hours is more preferably 200 ppm or lower, and still more preferably 120 ppm or lower.

A cathode active material for a lithium ion battery is constituted of primary particles and secondary particles formed by aggregation of primary particles, or a mixture of primary particles and secondary particles. In the cathode active material for a lithium ion battery, the average particle diameter of the primary particles or the secondary particles is preferably 2 to 15 μm.

If the average particle diameter is smaller than 2 μm, the application of the cathode active material on a current collector becomes difficult. If the average particle diameter is larger than 15 μm, voids are liable to be generated in the filling time, leading to a decrease in the filling property. The average particle diameter is more preferably 3 to 10 μm.

(Constitutions of a Cathode for a Lithium Ion Battery and a Lithium Ion Battery Using the Cathode)

A cathode for a lithium ion battery according to an embodiment of the present invention has a structure in which a cathode mixture prepared by mixing, for example, the cathode active material for a lithium ion battery having the above-mentioned constitution, an electroconductive aid, and a binder is provided on one surface or both surfaces of a current collector composed of an aluminum foil or the like. Further a lithium ion battery according to an embodiment of the present invention has a cathode for a lithium ion battery having such a constitution.

(Method for Producing a Cathode Active Material for a Lithium Ion Battery)

Then, a method for producing a cathode active material for a lithium ion battery according to an embodiment of the present invention will be described in detail.

First, a metal salt solution is prepared. The metals are Ni, and one or more selected from Sc, Ti, V, Cr, Mn, Fe, Co, Cu, Zn, Ga, Ge, Al, Bi, Sn, Mg, Ca, B, and Zr. The metal salts are sulfate salts, chlorides, nitrate salts, acetate salts, or the like, and are especially preferably nitrate salts. This is because even if there occurs mingling thereof as impurities in a firing raw material, since the nitrate salts can be fired as they are, a washing step can be omitted, and because the nitrate salts function as an oxidizing agent and have a function of promoting the oxidization of the metals in the firing raw material. Each metal contained in the metal salts is adjusted so as to be in a desired molar ratio. The molar ratio of the each metal in a cathode active material is thereby determined.

Then, lithium carbonate is suspended in pure water; and the metal salt solution of the above metals is charged therein to thereby prepare a metal carbonate salt solution slurry. At this time, microparticulate lithium-containing carbonate salts are deposited in the slurry.

In the case where lithium compounds such as of the sulfate salts and the chlorides as the metal salts do not react in a heat treatment, the deposited microparticles are washed with a saturated lithium carbonate solution, and thereafter filtered out. In the case where lithium compounds such as of the nitrate salts and the acetate salts react in the heat treatment as a lithium raw material, the deposited microparticles are not washed, and filtered out as they are, and dried to thereby make a firing precursor.

Then, the filtered-out lithium-containing carbonate salts are dried to thereby obtain a powder of a composite material (precursor for a lithium ion battery cathode material) of lithium salts.

Then, a firing vessel having a predetermined volume is prepared; and the powder of the precursor for a lithium ion battery cathode material is filled in the firing vessel. Then, the firing vessel filled with the powder of the precursor for a lithium ion battery cathode material is transferred into a firing oven, and the powder is fired. The firing is carried out by holding the heating for a predetermined time in an oxygen atmosphere. If the firing is carried out under pressure of 101 to 202 kPa, since the amount of oxygen in the composition increases, the firing is preferable.

Thereafter, the powder is taken out from the firing vessel, and crushed by using a commercially available crusher or the like to thereby obtain a powder of a cathode active material. The crushing is carried out so as not to generate as few micro powders as possible by suitably regulating the crushing strength and the crushing time specifically so that micro powder of 4 μm or smaller in particle diameter is 10% or less in terms of volume fraction, or so that the specific surface area of the powder becomes 0.40 to 0.70 m^2/g.

By controlling the generation of micro powder in the crushing time in such a manner, since the surface area of the powder per volume decreases, the area of the powder exposed to the air can be suppressed. Therefore, the moisture absorption of the power of the precursor in the storing time and the like can well be suppressed.

EXAMPLES

Hereinafter, Examples are provided in order to well understand the present invention and its advantages, but the present invention is not limited to these Examples.

Examples 1 to 17

Lithium carbonate in an amount of charging shown in Table 1 was suspended in 3.2 L of pure water, and thereafter, 4.8 L of a metal salt solution was charged therein. Here, the metal salt solution was prepared by adjusting a hydrate of a nitrate salt of each metal so that the each metal was at a compositional ratio shown in Table 1, and so that the number of moles of the whole metal became 14 moles.

The amount of lithium carbonate suspended was such an amount that x in $Li_xNi_{1-y}M_yO_{2+\alpha}$ of a product (lithium ion secondary battery cathode material, that is, a cathode active material) became a value in Table 1, which was calculated by the following expression.

$$W(g)=73.9\times14\times(1+0.5x)\times A$$

In the above expression, "A" is a multiplying numerical value involving, in addition to an amount necessary for the deposition reaction, previously subtracting an amount of lithium of lithium compounds excluding lithium carbonate remaining in the raw material after the filtering from the amount of suspension. "A" is 0.9 in the case where lithium salts such as of the nitrate salts and the acetate salts reacts as a firing raw material, and 1.0 in the case where lithium salts such as of the sulfate salts and the chlorides do not react as a firing raw material.

The microparticulate lithium-containing carbonate salts thus deposited in the solution by this treatment, and the deposits were filtered out using a filter press.

Then, the deposits were dried to thereby obtain a lithium-containing carbonate salt (precursor for a lithium ion battery cathode material).

Then, a firing vessel was prepared, and the lithium-containing carbonate salt was filled in the firing vessel. Then, the firing vessel was put in an oxygen-atmosphere oven in the atmospheric pressure, and heated and held at a firing temperature shown in Table 1 for 10 hours, and then cooled to thereby obtain an oxide.

Then, the obtained oxide was crushed using a pulverizing machine so that the micro powder of 3 μm or smaller in particle diameter had a predetermined volume fraction after the crushing, to thereby obtain a powder for a lithium ion secondary battery cathode material.

Example 18

In Example 18, the same process was carried out as in Examples 1 to 17, except for using a composition shown in Table 1 of each metal as the raw material, using chlorides as the metal salts, and washing the deposit with a saturated lithium carbonate solution and filtering the resultant after a lithium-containing carbonate salt was deposited.

Example 19

In Example 19, the same process was carried out as in Examples 1 to 17, except for using a composition shown in Table 1 of each metal as the raw material, using sulfate salts as the metal salts, and washing the deposit with a saturated lithium carbonate solution and filtering the resultant after a lithium-containing carbonate salt was deposited.

Example 20

In Example 20, the same process was carried out as in Examples 1 to 17, except for using a composition shown in Table 1 of each metal as the raw material, and carrying out the firing under pressure of 120 kPa in place of the atmospheric pressure.

Example 21

In Example 21, the same process was carried out as in Examples 1 to 17, except for using a composition shown in Table 1 of each metal as the raw material, and carrying out the crushing step in an atmosphere of a humidity of 60% or lower.

Comparative Examples 1 to 3

In Comparative Examples 1 to 3, the same process was carried out as in Examples 1 to 17, except for using a composition shown in Table 1 of each metal as the raw material, and carrying out no regulation as in Examples 1 to 17 of the crushing of the oxide as the final step.

Comparative Examples 4 to 6

In Comparative Examples 4 to 6, the same process was carried out as in Comparative Example 1, except for using a composition shown in Table 1 of each metal as the raw material, and carrying out the firing step in an air-atmosphere oven in place of the oxygen-atmosphere oven.

(Evaluations)

—Evaluation of a Cathode Material Composition—

The metal content of a cathode material was measured by an inductively coupled plasma atomic emission spectrometer (ICP-OES), and the compositional ratio (molar ratio) of each metal was calculated. The oxygen content was measured by a LECO method, and a was calculated. These numerical values were as shown in Table 1.

—Evaluation of an Average Particle Diameter—

A powder of each cathode material was sampled, and the average particle diameter was measured by a particle size distribution measuring device.

—Evaluation (1) of a Moisture Content—

A powder of each cathode material was stored in a closed state of a desiccator placed at room temperature; and the powder was suitably taken out and subjected to Karl Fischer titration with the titration speed being regulated at 0.15 mL/min under observation of a flowmeter of a vaporization apparatus to thereby measure moisture contents at 300° C. and 150° C. The measurement was carried out in a glove box filled with nitrogen gas. 50 mL of dehydrated ethanol and 100 mL of AQUALYTE RSA (made by Kanto Chemical Co., Inc.) were injected in an electrolytic cell. 15 mL of AQUALYTE CN (made by Kanto Chemical Co., Inc.) was injected in a counter electrode cell.

—Evaluation (2) of a Moisture Content—

A powder of each cathode material was left in the air at a humidity of 50% and at 25° C. for 24 hours, and immediately subjected to Karl Fischer titration with the titration speed being regulated at 0.15 mL/min under observation of a flowmeter of a vaporization apparatus to thereby measure a moisture content at 150° C. The measurement was carried out in a glove box filled with nitrogen gas. 50 mL of dehydrated ethanol and 100 mL of AQUALYTE RSA (made by Kanto Chemical Co., Inc.) were injected in an electrolytic cell. 15 mL of AQUALYTE CN (made by Kanto Chemical Co., Inc.) was injected in a counter electrode cell.

—Evaluation (3) of a Moisture Content—

A powder of each cathode material was left at a dew point of −80° C. for 24 hours, and immediately subjected to Karl Fischer titration with the titration speed being regulated at 0.15 mL/min under observation of a flowmeter of a vaporization apparatus to thereby measure a moisture content at 150° C. The measurement was carried out in a glove box filled with nitrogen gas. 50 mL of dehydrated ethanol and 100 mL of AQUALYTE RSA (made by Kanto Chemical Co., Inc.) were injected in an electrolytic cell. 15 mL of AQUALYTE CN (made by Kanto Chemical Co., Inc.) was injected in a counter electrode cell.

—Evaluation of Battery Properties—

Each cathode material, an electroconductive material, and a binder were weighed in a proportion of 85:8:7; the cathode material and the electroconductive material were mixed with a solution in which the binder was dissolved in an organic solvent (N-Methylpyrrolidone) to thereby make a slurry; and the slurry was applied on an Al foil, dried, and thereafter pressed to thereby make a cathode. Then, a 2032-type coin cell with Li as a counter electrode for evaluation was fabricated; and a discharge capacity at a current density of 0.2 C was measured using an electrolyte solution in which 1 M-$LiPF_6$ was dissolved in EC-DMC (1:1). Further a rate characteristic was acquired by calculating the ratio of a discharge capacity at a current density of 2 C to a battery capacity at a current density of 0.2 C. A capacity retention rate was measured by comparing an initial discharge capacity obtained at room temperature at a discharge current of 1 C and a discharge capacity after 100 cycles.

These results are shown in Tables 1 and 2.

TABLE 1

	Amount of Lithium Carbonate Suspended	Compositional Ratio of Each Metal in Whole Metal Excluding Li										Holding Temperature			Micro powder of 3 μm or Smaller in Particle Diameter after Crushing
	(g)	Ni	Co	Mn	Ti	Cr	Fe	Cu	Al	Sn	Mg	(° C.)	x	α	(vol %)
Example 1	1393	33.3	33.3	33.3								1000	1	0.15	6.2
Example 2	1393	33.3	33.3	33.3								1000	1	0.12	5.2
Example 3	1393	33.3	33.3	33.3								1000	1	0.15	4.9
Example 4	1393	33.3	33.3	33.3								1000	1	0.14	4.3
Example 5	1442	33.3	33.3	33.3								970	1.025	0.17	6.3
Example 6	1393	33.3	33.3	33.3								950	1.05	0.19	5.3
Example 7	1393	33	33	33						1		1000	1	0.11	4.9
Example 8	1393	60	15	25								920	1	0.17	6.1
Example 9	1393	60	15	25								900	1	0.15	6.8
Example 10	1393	80	10	10								900	1	0.12	6
Example 11	1393	80	10	10								900	1.01	0.10	6
Example 12	1393	80	10	10								800	1	0.11	4.9
Example 13	1393	80	15		2.5						2.5	800	1	0.13	6.7
Example 14	1393	80	15			5						800	1	0.11	6.2
Example 15	1393	80	15				5					800	1	0.21	6.6
Example 16	1393	80	15					5				800	1	0.11	6.2
Example 17	1393	80	15						5			750	1.01	0.13	6.1
Example 18	1393	33.3	33.3	33.3								1000	1	0.13	6.8
Example 19	1393	33.3	33.3	33.3								1000	1	0.10	6.9
Example 20	1393	33.3	33.3	33.3								950	1	0.23	4.1
Example 21	1393	80	10	10								900	0.99	0.12	4
Comparative Example 1	1393	33.3	33.3	33.3								1000	1	0.18	8.1
Comparative Example 2	1393	60	15	25								920	1	0.09	8.3
Comparative Example 3	1393	80	10	10								800	1	0.12	9
Comparative Example 4	1393	80	10	10								800	1	−0.01	8
Comparative Example 5	1393	80	15						5			800	1	−0.01	8.6
Comparative Example 6	1393	80	15		2.5						2.5	800	1.01	0.00	7.8

TABLE 2

	Average Particle Diameter (μm)	Moisture Content (a) at 300° C. (ppm)	Moisture Content (b) at 150° C. (ppm)	a − b (ppm)	Moisture Content at 150° C. after being Left at a Humidity of 50% at 25° C. for 24 hours (ppm)	Moisture Content at 150° C. after being Left at a Dew Point of −80° C. for 24 hours (ppm)	Discharge Capacity (mAh/g)	Rate Characteristic (%)	Capacity Retention Rate (%)
Example 1	6.2	260	130	130	650	150	153	92	92
Example 2	8.1	230	90	140	800	150	154	92	91
Example 3	10.2	240	100	140	700	200	157	95	92
Example 4	9.7	240	90	150	700	200	155	95	93
Example 5	5.1	250	110	140	700	150	155	93	92
Example 6	9	290	160	130	800	150	160	92	89
Example 7	10.1	290	120	170	800	200	158	92	88
Example 8	10	280	160	120	650	200	175	88	87
Example 9	7.9	250	130	120	700	200	172	89	88
Example 10	7.9	750	400	350	950	350	185	87	84
Example 11	8.3	1050	550	500	1000	300	185	86	82
Example 12	10	250	150	130	800	250	195	87	85
Example 13	9.5	290	160	130	900	200	185	87	85
Example 14	10	270	140	130	800	200	186	88	84
Example 15	8.7	290	160	130	700	200	187	87	84
Example 16	7.8	270	130	140	700	200	180	88	83
Example 17	10.7	260	130	130	800	150	190	89	85
Example 18	9	260	120	130	700	150	153	90	87
Example 19	9	280	140	140	800	150	151	90	86
Example 20	9.4	280	140	140	800	150	156	95	93
Example 21	8	240	130	110	600	120	190	92	92
Comparative Example 1	7	1200	500	700	2500	450	153	88	85
Comparative Example 2	10	1200	600	600	3000	400	165	83	78
Comparative Example 3	11	1400	600	700	2000	400	180	83	82
Comparative Example 4	9	1500	700	800	1300	400	170	80	78

TABLE 2-continued

	Average Particle Diameter (μm)	Moisture Content (a) at 300° C. (ppm)	Moisture Content (b) at 150° C. (ppm)	a − b (ppm)	Moisture Content at 150° C. after being Left at a Humidity of 50% at 25° C. for 24 hours (ppm)	Moisture Content at 150° C. after being Left at a Dew Point of −80° C. for 24 hours (ppm)	Discharge Capacity (mAh/g)	Rate Characteristic (%)	Capacity Retention Rate (%)
Comparative Example 5	10	1300	500	800	1200	400	165	75	75
Comparative Example 6	8.9	1200	550	650	1700	500	171	79	74

Any of Examples 1 to 21 could provide compositions prescribed in the present invention, and exhibited a moisture content measured by Karl Fischer titration at 300° C. of 1100 ppm or lower, and were good in any of the discharge capacity, the rate characteristic, and the capacity retention rate.

Comparative Examples 1 and 3 exhibited a moisture content exceeding 1100 ppm as measured by Karl Fischer titration at 300° C., and were poor in the rate characteristic and the capacity retention rate.

Comparative Examples 2, 4, 5, and 6 could not provide compositions prescribed in the present invention, and exhibited a moisture content exceeding 1100 ppm as measured by Karl Fischer titration at 300° C., and were poor in the rate characteristic and the capacity retention rate.

The invention claimed is:

1. A cathode active material for a lithium ion battery, represented by a composition formula:

$$Li_xNi_{1-y}M_yO_{2+\alpha}$$

wherein M is one or more selected from Sc, Ti, V, Cr, Mn, Fe, Co, Cu, Zn, Ga, Ge, Al, Bi, Sn, Mg, Ca, B, and Zr; $0.9\leq x\leq 1.2$; $0<y\leq 0.7$; and $\alpha>0.1$,

wherein a first moisture content measured by Karl Fischer titration at 300° C. is 1,100 ppm or lower and,

a difference between the first moisture content measured by Karl Fischer titration at 300° C. and a second moisture content measured by Karl Fischer titration at 150° C. is 100to 500 ppm;

further wherein a third moisture content measured by Karl Fischer titration at 150° C. is 300 ppm or lower after the cathode active material is left at a dew point of −80° C. for 24 hours.

2. The cathode active material for a lithium ion battery according to claim **1**, wherein the first moisture content measured by Karl Fischer titration at 300° C. is 800 ppm or lower.

3. The cathode active material for a lithium ion battery according to claim **1**, wherein the M is one or more selected from Mn and Co.

4. The cathode active material for a lithium ion battery according to claim **1**, wherein $\alpha>0.15$ in the composition formula.

5. The cathode active material for a lithium ion battery according to claim **4**, wherein $\alpha>0.20$ in the composition formula.

6. The cathode active material for a lithium ion battery according to claim **1**, wherein the second moisture content measured by Karl Fischer titration at 150° C. is 300 ppm or lower.

7. The cathode active material for a lithium ion battery according to claim **6**, wherein the second moisture content measured by Karl Fischer titration at 150° C. is 200 ppm or lower.

8. The cathode active material for a lithium ion battery according to claim **1**, wherein the difference between the first moisture content measured by Karl Fischer titration at 300° C. and the second moisture content measured by Karl Fischer titration at 150° C. is 100 to 130 ppm.

9. The cathode active material for a lithium ion battery according to claim **1**, wherein a fourth moisture content measured by Karl Fischer titration at 150° C. is 1500 ppm or lower after the cathode active material is exposed to air at a humidity of 50% and at 25° C. for 24 hours.

10. The cathode active material for a lithium ion battery according to claim **9**, wherein the fourth moisture content measured by Karl Fischer titration at 150° C. is 1200 ppm or lower after the cathode active material is exposed to air at a humidity of 50% and at 25° C. for 24 hours.

11. The cathode active material for a lithium ion battery according to claim **1**, wherein the third moisture content measured by Karl Fischer titration at 150° C. is 200 ppm or lower after the cathode active material is left at a dew point of −80° C. for 24 hours.

12. A cathode for a lithium ion battery, using a cathode active material for a lithium ion battery according to claim **1**.

13. A lithium ion battery, using a cathode for a lithium ion battery according to claim **12**.

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